some of the things that traditional models cannot do. I'm convinced it is worth a try. Now, where is my random number generator?

REFERENCES

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The Number Sense: How the Mind Creates Mathematics. By Stanislas Dehaene. Oxford University Press, 1997, xi + 274 pp., $25.00.

Reviewed by **Reuben Hersh**

Stanislas Dehaene is a French cognitive scientist. He was once a graduate student of mathematics. This clear, friendly book offers to explain "how the mind creates mathematics." It brings together fascinating evidence from dozens of sources in linguistics, experimental neuroscience, developmental and comparative psychology.

After reading it, I'm convinced that something in our brains underlies and makes possible mathematical thinking. Brain researchers are beginning to find out what it is and where it is!

Here are some sample tidbits:

> *Epilepsia arithmetices* is a syndrome first reported in 1962 by the neurologists D. Ingvar and G. Nyman. During a routine electroencephalographical examination of an epileptic girl, they discovered that whenever their patient solved arithmetic problems, even very simple ones, her brain waves showed rhythmic discharges. Calculation triggered epileptic fits, while other intellectual activities such as reading had no effect. ... More than a dozen similar cases of "arithmetic epilepsy" are now known throughout the world.

> Between 5% and 10% of humanity is thoroughly convinced that numbers have colors and occupy very precise locations in space. In the 1880s already, Sir John Galton remarked that several acquaintances, most of them women, gave numbers extraordinarily precise and vivid qualities that were incomprehensible to anyone else. One of them described numbers as a ribbon undulating rightward, richly colored in shades of blue, yellow, and red.... A recent survey, conducted a century after Galton's, found similar images of numbers in modern university students.... Most people associate black and white with either 0 and 1 or 8 and 9; yellow, red, and blue with small numbers such as 2, 3, and 4; and brown, purple, and gray with larger numbers such as 6, 7, and 8.

The chapter titles give a good sense of what's in the book. There are three Parts, each containing three chapters. Part I, *Our Numerical Heritage*, contains "Talented and Gifted Animals" (horses, rats, chimpanzees), "Babies Who Count" (4 months old), and "The Adult Number Line" (for larger numbers, the distance between numbers is compressed). Part II, *Beyond Approximation*, contains "The Language of Numbers" (hints about the psychology of number suggested by number words in many languages), "Small Heads for Big Calculations" (psychological issues in elementary math education), and "Geniuses and Prodigies" (including Idiot Sa-

vants and Ramanujan). Part III, *Of Neurons and Numbers*, contains "Losing Number Sense" (the effect on mathematical thinking of various brain diseases and injuries), "The Computing Brain" (why the digital computer is not an appropriate model for the brain), and "What is a Number?" (philosophical consequences of psychoneurological knowledge).

Dehaene comments on the nature of mathematical reality as follows:

> For an epistemologist, a neurobiologist, or a neuropsychologist, the Platonist position seems hard to defend. ... Even if mathematicians' introspection convinces them of the tangible reality of the objects they study, this feeling cannot be more than an illusion. Presumably, one can become a mathematical genius only if one has an outstanding capacity for forming vivid mental representations of abstract mathematical concepts—mental images that soon turn into an illusion, eclipsing the human origins of mathematical objects and endowing them with the semblance of an independent existence.

Among the remarkable ideas suggested here is that there is a special neural system for recognizing and counting small sets, of up to three members; something similar is possessed by many animal species. Also, the basic neurological systems for determining size are not digital but analog; we naturally estimate "how big?" in an approximate sense, and only later try to make the answer a precise number.

Dehaene summarizes four of his main propositions as follows.

1. The human baby is born with innate mechanisms for individuating objects and for extracting the numerosity of small sets.
2. This "number sense" is also present in animals, and hence it is independent of language and has a long evolutionary history.
3. In children, numerical estimation, comparison, counting, simple addition and subtraction all emerge spontaneously without much explicit instruction.
4. The inferior parietal region of both cerebral hemispheres hosts neuronal circuits dedicated to the mental manipulation of numerical quantities.

He goes on:

> Intuition about numbers is thus anchored deep in our brain. Number appears as one of the fundamental dimensions according to which our nervous system parses the external world. Just as we cannot avoid seeing objects in color (an attribute entirely made up by circuits in our occipital cortex, including area V4) and at definite locations in space (a representation reconstructed by occipitoparietal neuronal projection pathways), in the same way numerical quantities are imposed on us effortlessly through the specialized circuits of our inferior parietal lobe. The structure of our brain defines the categories according to which we apprehend the world through mathematics.

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